ARMY RESEARCH LABORATORY

Methodology for Dynamic Characterization of Fragmenting Warheads

by Jason Angel

ARL-SR-179 **May 2009**

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5069

ARL-SR-179 **May 2009**

Methodology for Dynamic Characterization of Fragmenting Warheads

Jason Angel
Weapons and Materials Research Directorate, ARL

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
May 2009	Final	February 2007–September 2007

4. TITLE AND SUBTITLE
Methodology for Dynamic Characterization of Fragmenting Warheads

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Jason Angel

5d. PROJECT NUMBER
7884G1

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: AMSRD-ARL-WM-TC
Aberdeen Proving Ground, MD 21005-5069

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-SR-179

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Fragmentation is characterized by a static arena test. In this test, fragmentation data are assembled in a Z-data file, which serves as input to lethality models and includes the velocity and angle of inclination of the warhead to estimate the lethal area of fragmentation. In this report, a new method to confirm the Z-data file and the lethality methodology is proposed. As a test case, the 105-mm high-explosive plastic round was used. This round is a direct-fire projectile and was evaluated in both the dynamic and static modes. This projectile has a Z-data file that is well defined. In the test, metallic witness panels were placed in semi-circular patterns around the proposed burst location of the projectile. The impacts on the witness panels were then compared to the average number of impacts expected based on the Z-data file. The method added data needed to confirm the Z-data file in dynamic tests prior to fielding and also raised possible issues about the overall lethality models when using the current Z-data files.

15. SUBJECT TERMS
fragmenting warhead, Z-data file, dynamic event, fragment distribution, high explosive

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Jason Angel
Unclassified	Unclassified	Unclassified	UU	20	19b. TELEPHONE NUMBER (*Include area code*) 410-278-0600

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

1. Introduction

Current fragmenting warheads are characterized by a standardized *Joint Munitions Effectiveness Manual* (JMEM)[1] procedure. This procedure collects fragmentation data from a static test and produces a Z-data file. The Z-data file describes the fragmentation in polar zones by placing the number of fragments into separate mass categories and determining the overall velocity and shape characteristics. This Z-data is then combined with impact conditions such as velocity, orientation, angle, etc., to estimate the direction and velocity of the fragments. This is a statistical event, making it difficult to confirm or refute the results in a "live-fire" or dynamic event. Current practice is to accept the results from the JMEM testing and assume the translation to a dynamic event is correct, often without any additional experimentation until the live-fire evaluation. In the live-fire evaluation, mannequins are typically set in the target area and are assessed for their level of incapacitation. This procedure does not produce any statistical evidence of the fragment spray because typically a limited number of mannequins are placed intermittently within the target area.

For the typical live-fire evaluation of a direct-fire projectile against a specific target, e.g., the M829 round vs. the T72 tank, the process has many deterministic results. For a given impact location on the target, preshot predictions of the event are made, which consist of several deterministic events. Examples include the following factors:

- Does the projectile perforate the armor?
- What does the residual projectile impact inside the target?
- What does the spall impact inside the target?
- What is the damage to the components impacted?

Given these results, the overall probability of kill can be assessed. After the event, these results can be assessed using the exact impact location to answer the same questions. Although the spall is a statistical event, most of the other assessments are more deterministic and can be reviewed. For bursting munitions, the entire event is statistical, so the results are probabilistic and cannot be determined exactly to ascertain whether or not the fragmentation is behaving as expected based on the data currently collected.

This evaluation proposes a new method of collecting the fragmentation data in a dynamic event to provide a better representation of the entire fragment spray that would help to

[1]Headquarters, Department of the Army. Testing and Data Reduction Procedures for High-Explosive Munitions, Revision 2. In *Joint Munitions Effectiveness Manual*; FM-101-51-3; Washington, DC, May 1989.

confirm or refute the Z-data file and/or define if there are any extraordinary circumstances for the warhead in the dynamic mode (see figures 1–19).

The methodology will allow the program managers (PMs), users, and evaluators a better technique to show that the warhead is performing as expected in the dynamic event. Upon completing these evaluations, the PM can confirm the results for the lethality and collateral damage with much more confidence than previously possible from using only the JMEM data. The final analysis will correlate the data from the JMEM tests and the actual impact conditions of the warhead to the results obtained from the actual dynamic event to demonstrate that the warhead is indeed performing as expected. Therefore, the estimates of lethality and collateral damage will be developed with greater confidence than previously obtained.

This methodology is applicable to any fragmenting warhead evaluation. Currently, it has been proven beneficial to several systems including the Guided Multi-Launch Rocket System-Unitary (GMLRS-U) version, the precision-guided mortar munition, the Excalibur artillery round, and the 105-mm high-explosive plastic (HEP) projectile.

The PM for the 105-mm HEP projectile has agreed to furnish M393E3 warheads for the evaluation. The 105-mm HEP munition has been in the inventory since the 1940s. It is currently used as a wall-breaching munition, and there is a well-defined Z-data file for this munition. The 105-mm HEP is a direct-fire munition, so it will be ideal to prove the methodology.

The purpose of these evaluations is to define the dynamic fragment spray of the warheads so no specific targets will be used. Instead, metallic witness panels will be placed in an array around the attended impact area. The project will be conducted by the Weapons Materials Research Directorate of the U.S. Army Research Laboratory, and the test will be conducted at the U.S. Army Aberdeen Test Center by the large-caliber test team. Both phases will produce a comparison of the existing Z-data modeled as a dynamic event and the actual fragmentation spray from a dynamic event.

OUTLINE

BOTTOM LINE UP FRONT

1 - PROPOSED METHOD TO ASSESS FRAGMENTATION FOR DYNAMIC EVENT
2 – QUESTIONING EXISTING METHODOLOGY FOR FRAGMENTATION LETHALITY

- Background/Issues
- Approach
- Test Setup
- Results/Discussion
- Conclusions

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

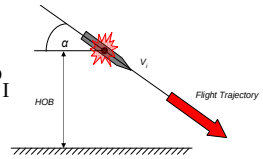
Figure 1. Outline.

BACKGROUND/ISSUES

CURRENT METHOD TO ASSESS FRAGMENTATION

- Static arena test
  - Statistical representation of the fragmentation
  - Fragmentation file (Z-data file)

- Lethality models use Z-data and dynamic impact conditions
  - Impact velocity, orientation, etc.
  - Predict number of impacts on personnel
  - Determine probability of incapacitation, P_I



- Currently no method to correlate to dynamic testing (just a probability of achieving a level of incapacitation)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Figure 2. Background/issues.

GMLRS as an EXAMPLE

- Z-data file established
- P_I for impact condition computed
- Performed dynamic event
    - Mannequins assessed for lethality
    - All personnel fell within bands (P_I +/-)

ISSUE – no statistical correlation to fragment spray

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Figure 3. GMLRS as an example.

APPROACH

- Goal:
    - Demonstrate method to collect fragmentation data in a dynamic event to produce higher statistical confidence in results

- Evaluation concept:
    - Use warhead with well-established Z-data file
    - Collect fragment spray via metallic witness panels located in an arena arrangement
    - Compare perforations in the panels from the detonated warheads to those predicted using the static arena file
        - Static event – no projectile velocity (serves as a baseline)
        - Dynamic event – incoming velocity will be applied

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Figure 4. Approach.

TEST ARTICLES

- 105-mm HEP round
  - Inventory since 1970s
  - New Z-data file recently produced
- Metallic witness panels

Statically detonated from platform

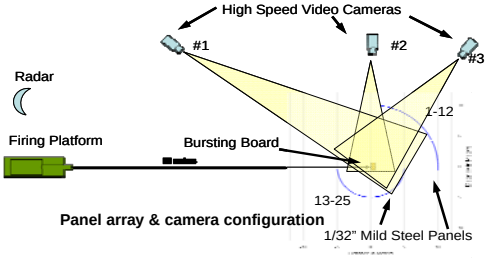
One side of panel arrangement

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Figure 5. Test articles.

TEST OVERVIEW

- Test setup:
  - Collect fragmentation with metallic panel array in "arena"
  - Dynamic – fire 105-mm HEP projectile through wood to detonate
  - Static – statically detonate HEP projectile
- Measurements:
  - Panel array surveyed prior to test
  - Photograph panels, use image software to record position of impacts
  - Dynamic – use radar and video to determine impact velocity and location of
  - warhead when it burst



Panel array & camera configuration

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Figure 6. Test overview.

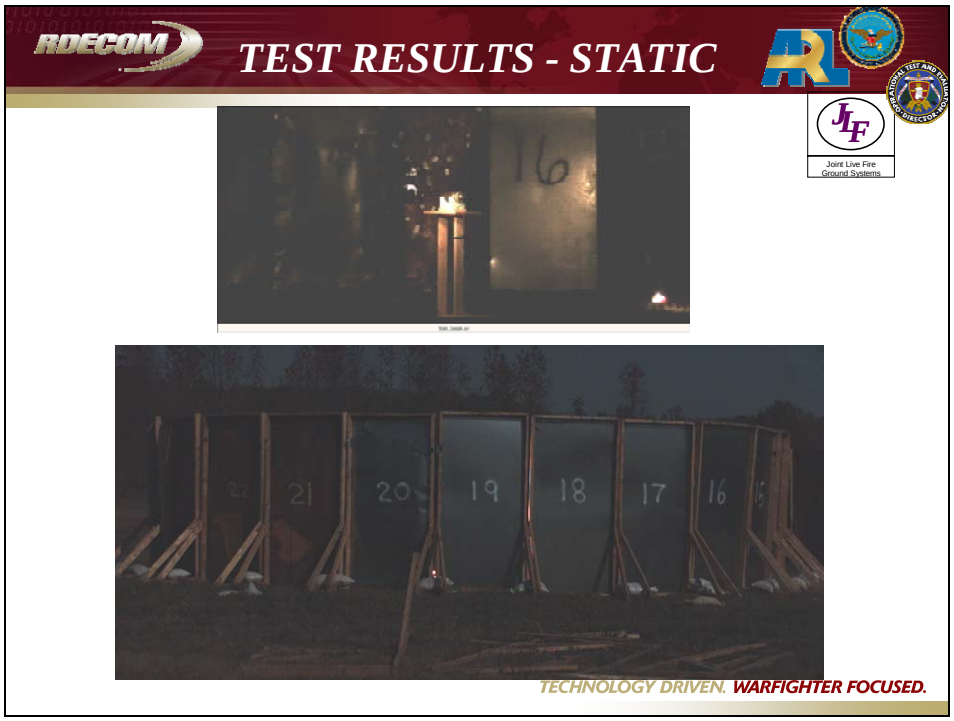


Figure 7. Test results (static).

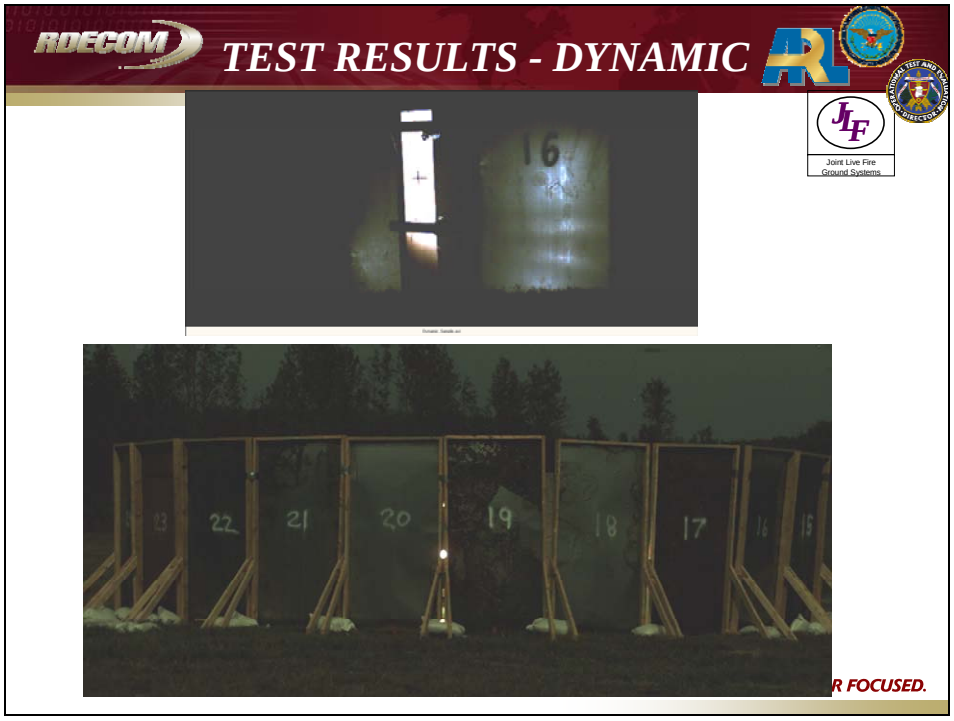


Figure 8. Test results (dynamic).

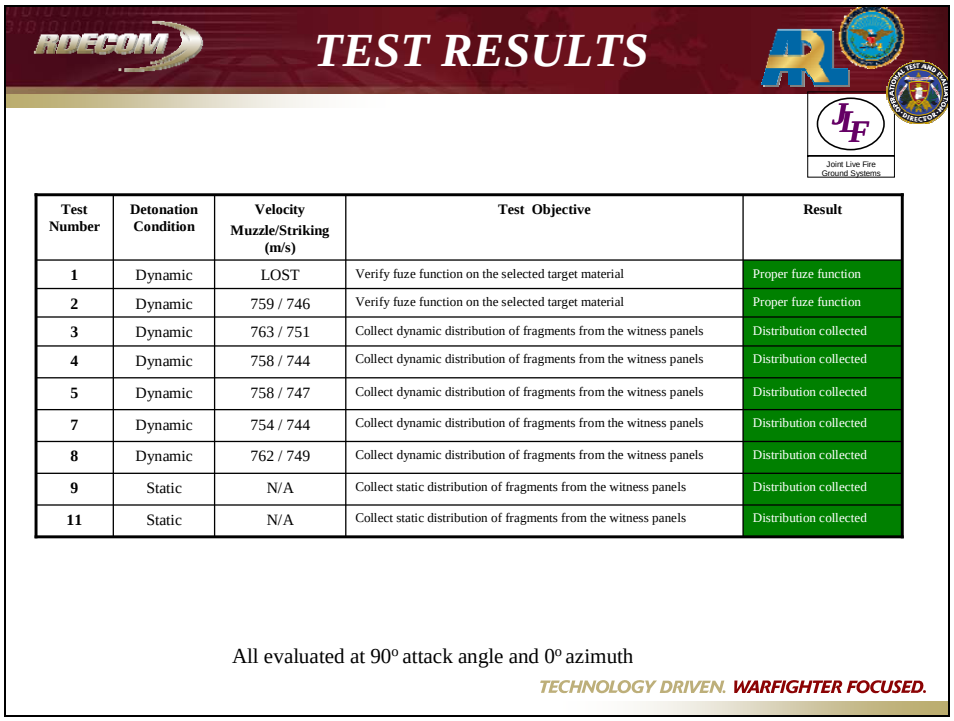


Figure 9. Phase 1 test results.

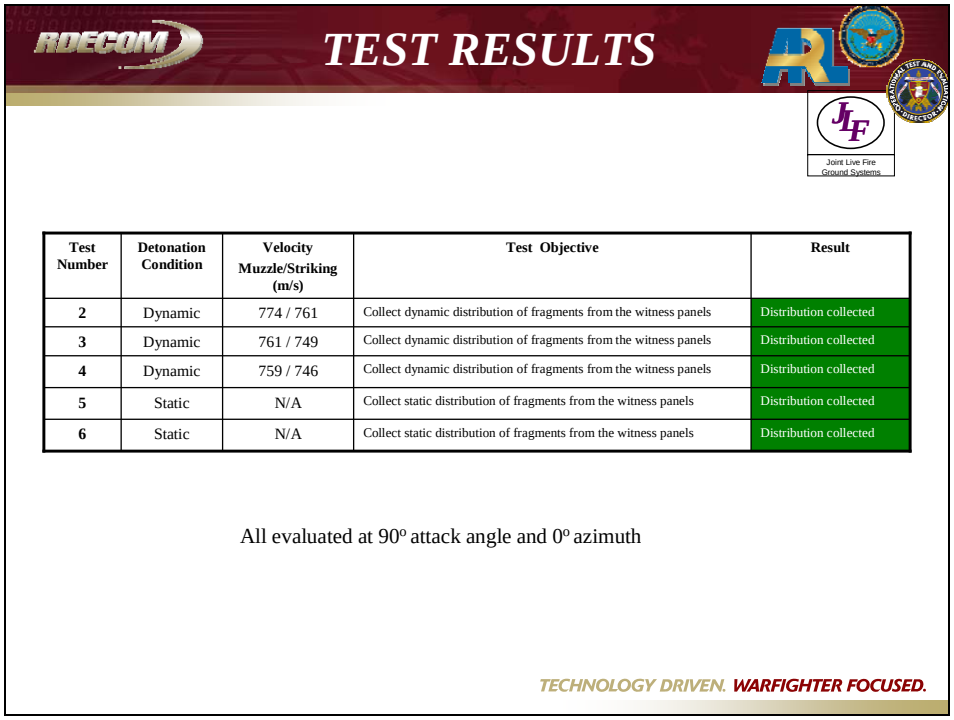


Figure 10. Phase 2 test results.

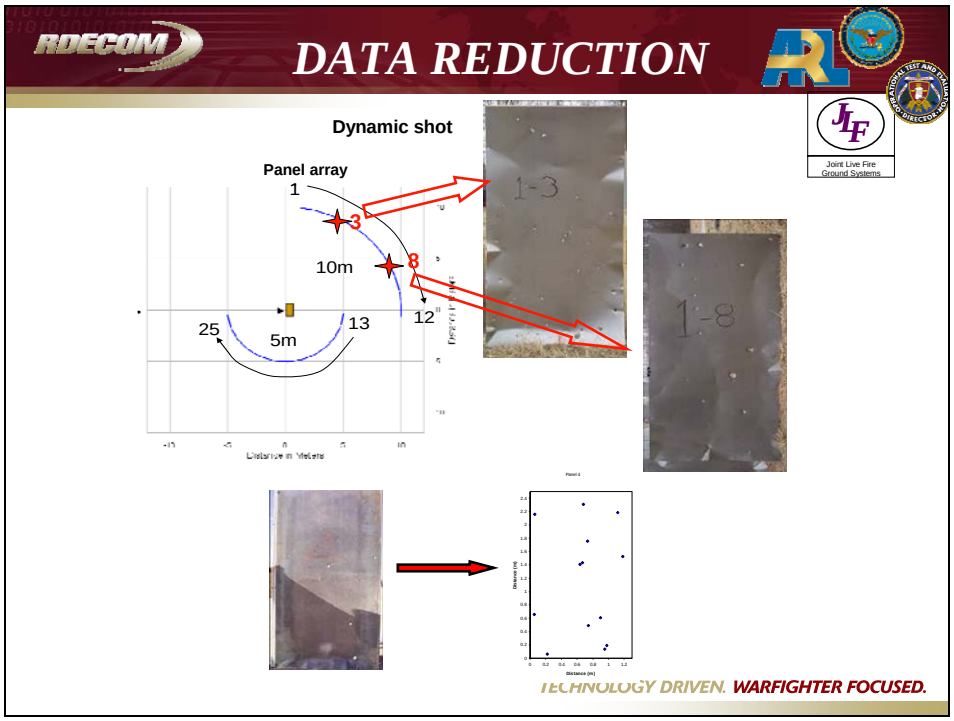


Figure 11. Data reduction.

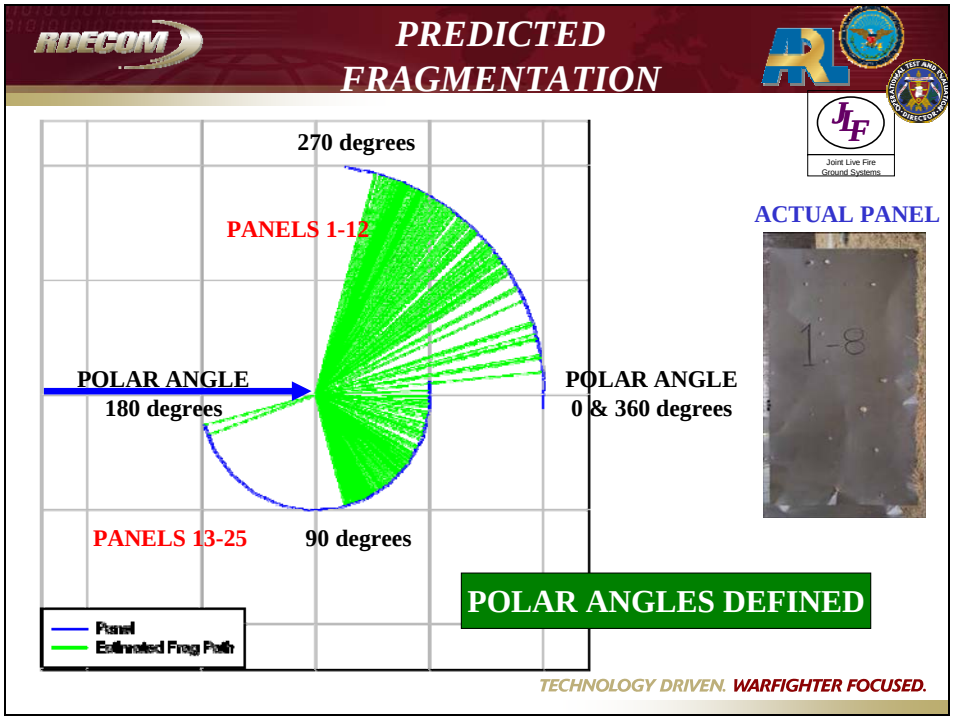


Figure 12. Predicted fragmentation.

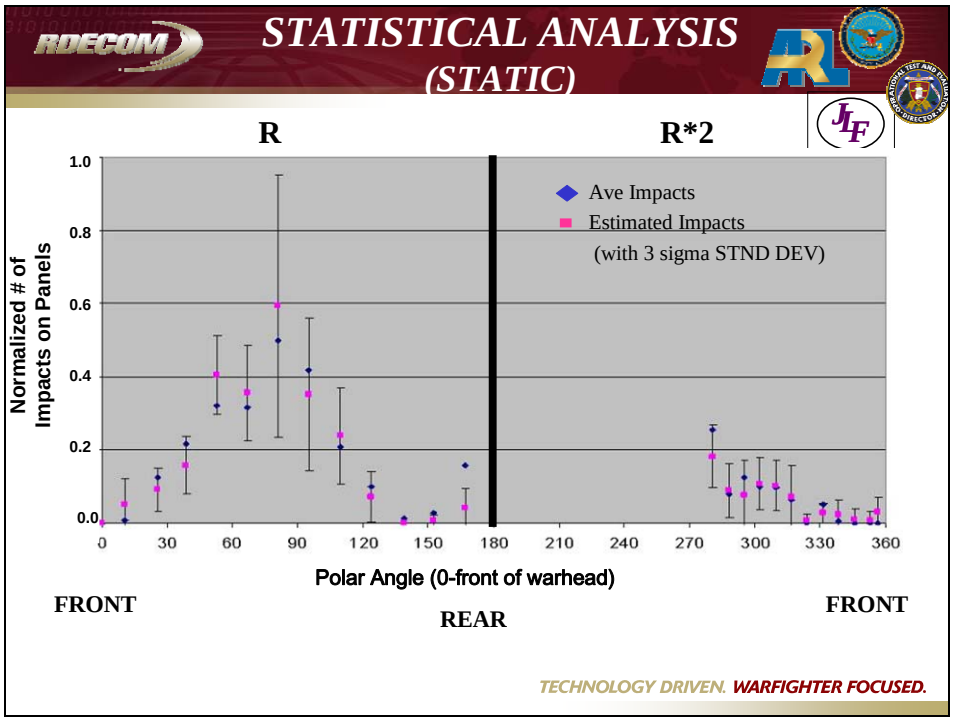


Figure 13. Statistical analysis (static).

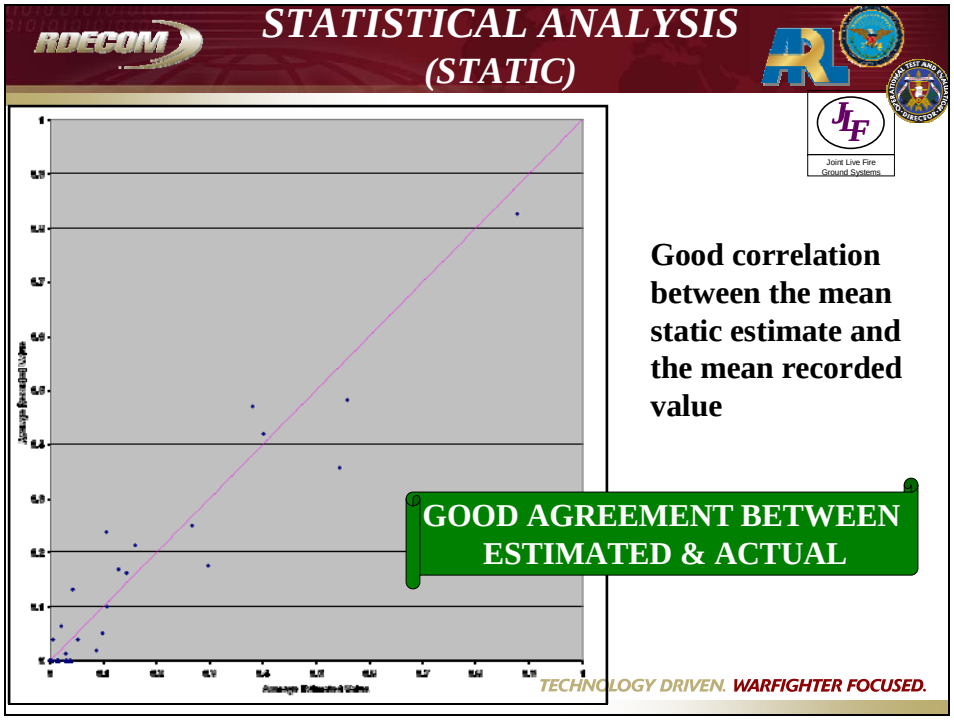


Figure 14. Statistical analysis (static correlation).

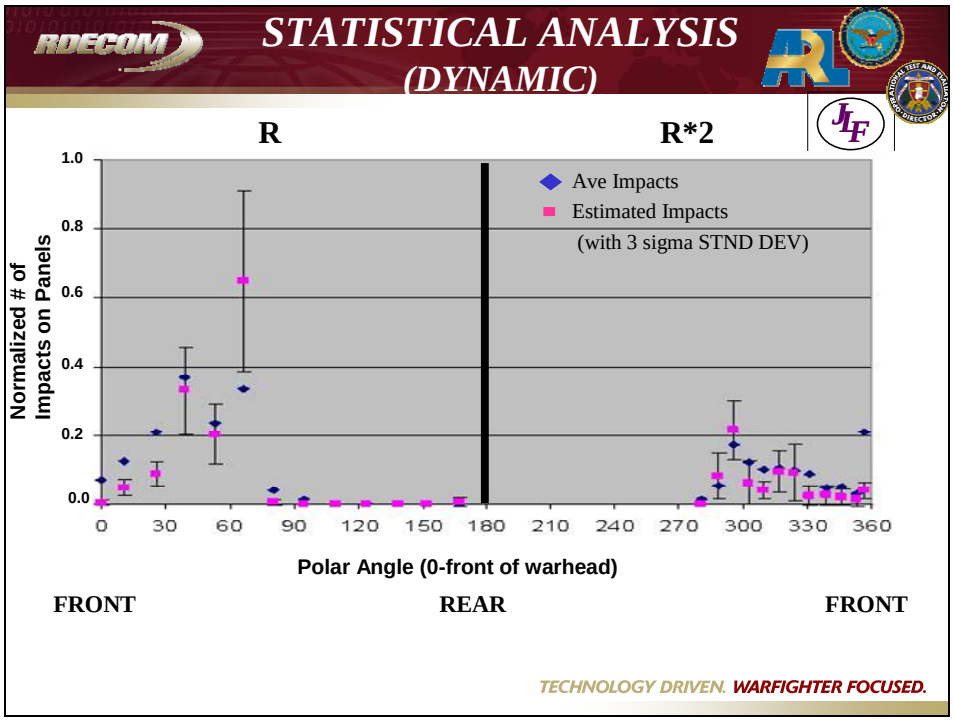


Figure 15. Statistical analysis (dynamic).

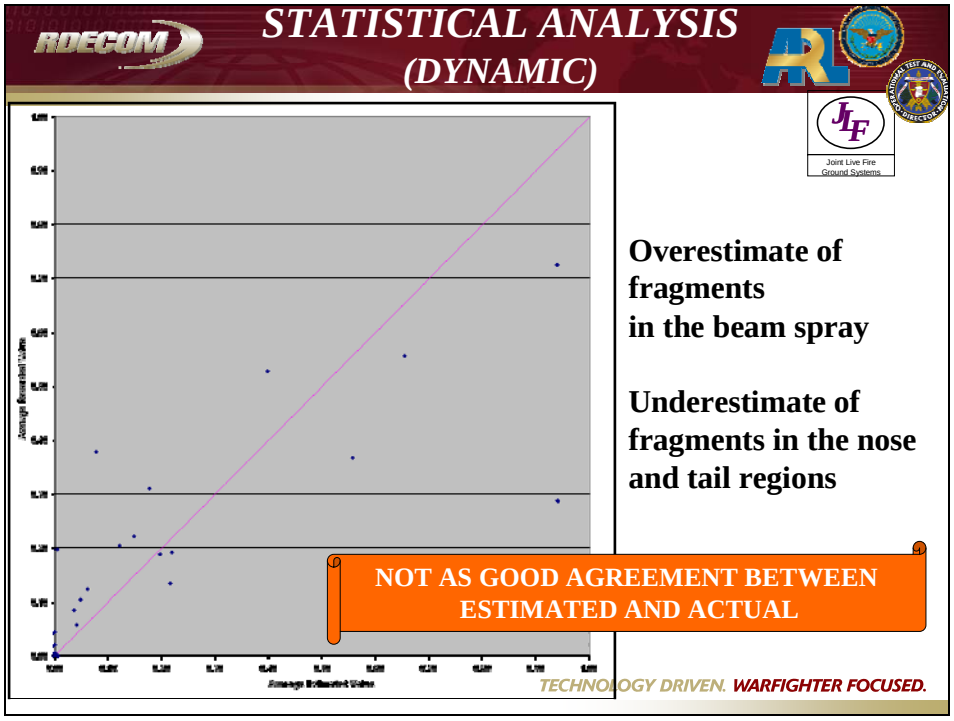


Figure 16. Statistical analysis (dynamic correlation).

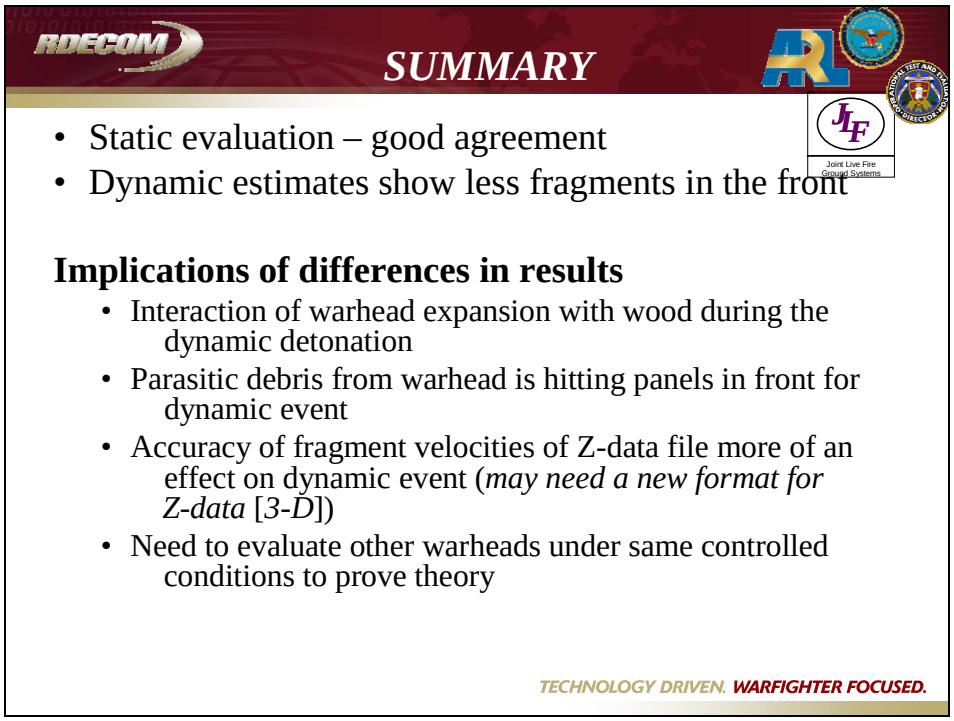


Figure 17. Summary.

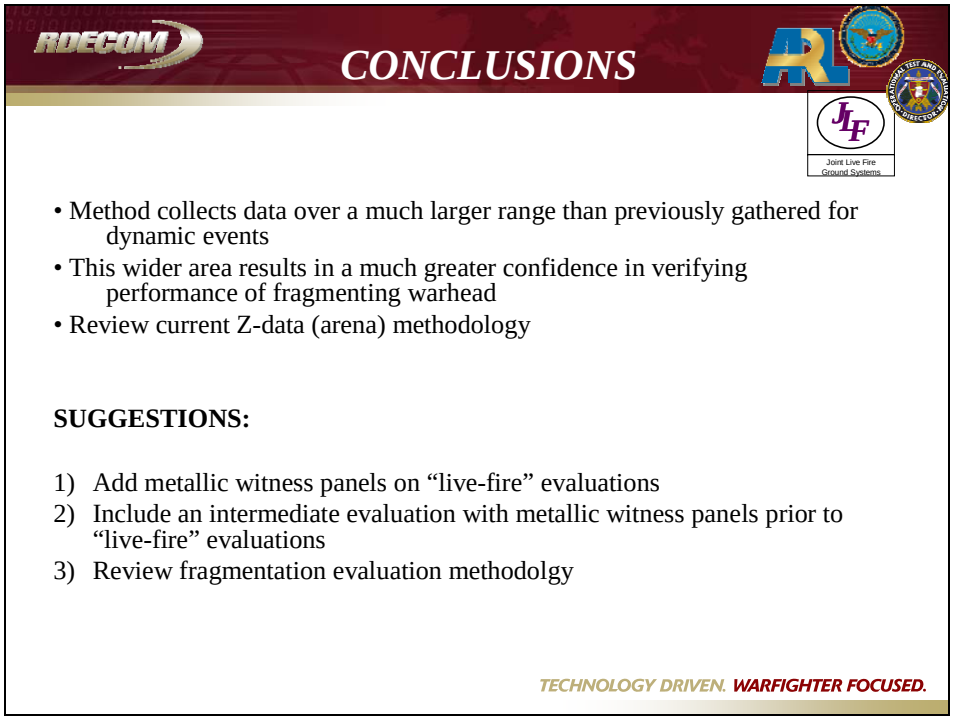


Figure 18. Conclusions.

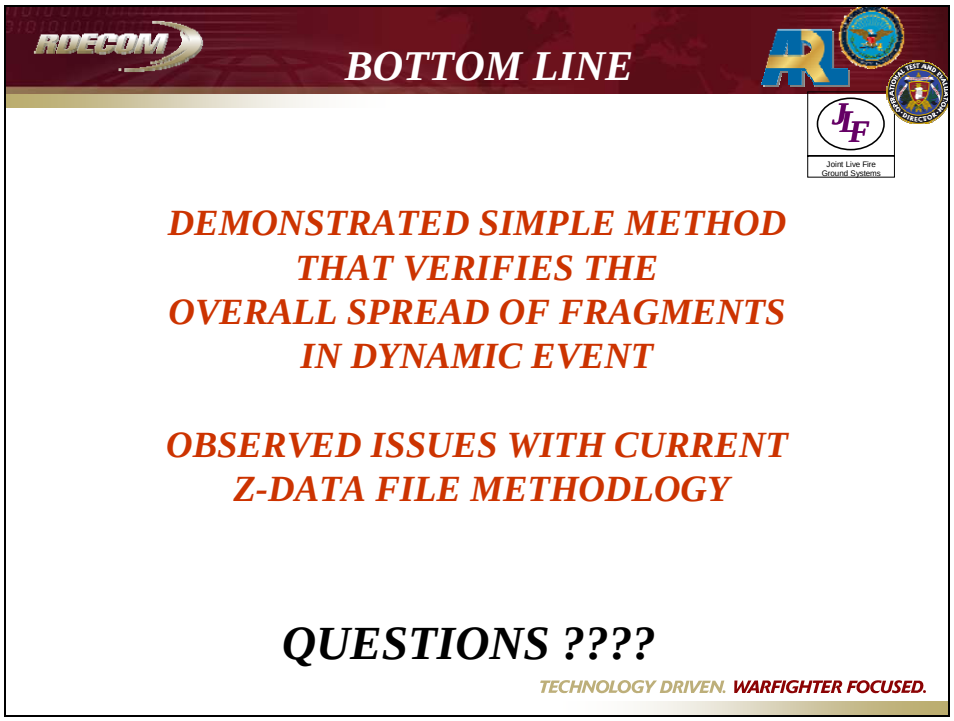


Figure 19. Bottom line.

NO. OF
COPIES ORGANIZATION

1 (PDF only) DEFENSE TECHNICAL INFORMATION CTR
DTIC OCA
8725 JOHN J KINGMAN RD
STE 0944
FORT BELVOIR VA 22060-6218

1 DIRECTOR
US ARMY RESEARCH LAB
IMNE ALC HRR
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RESEARCH LAB
AMSRD ARL CI OK TL
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RESEARCH LAB
AMSRD ARL CI OK PE
2800 POWDER MILL RD
ADELPHI MD 20783-1197

ABERDEEN PROVING GROUND

1 DIR USARL
AMSRD ARL CI OK TP (BLDG 4600)

NO. OF
COPIES ORGANIZATION

ABERDEEN PROVING GROUND

1 USAATC
CSTE DTC AT FP C
W ROUSH
BLDG 400
APG MD 21005-5059

14 DIR USARL
AMSRD ARL WM TC
J ANGEL (12 CPS)
T FARRAND
R SUMMERS